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ON THE

DISEASES OF REFRACTION

AND

ACCOMMODATION:

BY

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[From May No. Richmond and Louisville Medical Journal.]

Within the past few years no department of ophthalmological science has made such rapid progress as that relating to the diseases of refraction and accommodation.

I propose in this paper to give a brief account of the views on these subjects at present entertained, and of the most approved means of remedying them. Many cases of amblyopia, that a few years since would have been considered as incurable, are now entirely relieved by neutralizing the aberrations of refraction by appropriate lenses. It is definitely settled, that the inherent power possessed by the eye of adapting itself to see an object clearly and distinctly at different distances, is due to the voluntary action of the ciliary muscle on the crys-

talline lens; causing the latter to change its curvatures as the object approaches or recedes from the eye, so that, within certain limits, diverging rays coming from it are united in a focus on the retina. It was formerly supposed that both the iris and the external muscles of the eye-ball assisted in accommodation, but it has been found that in congenital absence of the iris, and in one instance of its accidental removal, the accommodation has been normal. I have myself met with a case of paralysis of the external muscles of the eye in which the accommodation remained perfect. If we take a small object (No. 1 Snellen) and hold it at the farthest distance at which the normal eye can distinctly and sharply see it, we have the far point (r), and this represents the natural refractive state of the dioptric apparatus. If we now bring the object to the nearest point at which it can be seen with equal clearness, we have the near point (p). The distance of each point from the eye is represented, respectively, by R and P. The distance between the far and near points is the range of accommodation (A), and the measure of any point on that line for which the eye may be accommodated, is the amount of adjustment. Practically, rays of light emanating from the far point of the normal eye are regarded as parallel, and as coming from an infinite distance (∞). The range of accommodation is found by the following formula: $A = \frac{1}{P} - \frac{1}{R}$. If the far point is 12''* (infinite distance), and the near point 4'', then $A = \frac{1}{4} - \frac{1}{\infty} = \frac{1}{4}$. Hence A represents a convex lens of 4'' focus, and the ciliary muscle has the power of changing the curvatures of the lens so as to add to it a power equal to a lens of 4''. The smallest angle at which the emmetropic eye can ordinarily see with distinctness, is one of five minutes, hence this has been adopted as the normal angle. Snellen has devised test types, each one representing an angle of five minutes, and numbered according to the number of feet they are to be held from the eye. If one can, without the assistance of the accommodation,

* The reader will observe that these symbols represent (') foot, ('') inch, and (''') line.

read No. 1 at 1′, and No. 20 at 20′, he has normal vision, and his eyes are emmetropic (V = 1). Some eyes can see at a smaller angle than five minutes. If No. 20 can be read at 30′ and No. 1 at 18″, then the sharpness of vision is greater than normal, and is expressed by $V = \frac{18}{12}$, or $\frac{30}{20}$. If No. 20 can only be read at 10′, then $V = \frac{10}{20}$, and the sharpness of vision is diminished one-half.

When the natural refractive state of the dioptric apparatus falls too low to unite parallel rays in a focus on the bacillar layer, but is adjusted for virtual images behind the retina, the eye is said to be hypermetropic, and, unless assisted by the accommodation, sees objects indistinctly. When in the emmetropic eye the near point recedes beyond 8″, it is said to be presbyopic. The convexity of the cornea often varies in its different meridians. When this is the case, planes of homocentric light falling on the different meridians are not united at the same point, but those falling on the most convex meridian are united first, and those upon the meridian least convex last. This is astigmatism of the cornea. If similar inequalities exist in the lens, it produces lenticular astigmatism. The ocular axis and visual axis are not the same. The former corresponds with the long axis of the cornea, and is represented by a line drawn from its vertex through the posterior schleral pole—which is about midway between the external edge of the optic disk and the yellow spot. The latter—that is, the axis of the vision or optic axis—corresponds with the axis of the lens, and is represented by the visual line, which passes from the yellow spot—the point of direct vision—through the nodal point—the optical centre of the eye—to the point of fixation, usually cuts the cornea inside of its zenith, and slightly below its horizontal meridian. The horizontal deviation in the normal eye varies from two to three degrees; in the hypermetropic eye from three to nine degrees, while in the high grades of myopia, the visual line may cut the cornea outside of its zeninth. These variations in the visual lines have a marked influence upon the degree of convergence necessary in

the different abnormal conditions of the eyes, and often give rise to an apparent squint. When a small object is slowly moved towards the eyes, the ciliary, the internal recti, and the circular muscles of the iris gradually contract, until the near point is reached; then the two former muscles are in a maximum state of tension; as the object recedes, these relax until it reaches the far point, when the ciliary and internal recti muscles are in a minimum state of contraction.

There is in binocular vision an intimate association between accommodation and convergence. With a certain amount of accommodation we have a certain amount of convergence, and, *vice versa*, with a certain amount of convergence there is a corresponding amount of accommodation; but these relations are not absolute; for, with the same convergence, an object may be brought a little nearer, or receded from the eye, without interfering with the sharpness of vision. The difference is relative accommodation. Then again, with a certain amount of accommodation the convergence may be slightly increased or diminished without disturbing vision. This variation represents relative convergence. For easy vision, relative convergence and relative accommodation must bear a certain proportion to each other, and these relations cannot long be disturbed without inducing retino-ciliary hyperæmia and its attendant symptoms. In relative accommodation—that is, the maximum variation that can take place with a certain convergence—that part induced by relaxation of the ciliary muscle is negative, while that caused by an increased muscular tension is positive. The positive must bear to the negative a relation of about three to two.—[*Loring.*]

These relative associations only represent possible conditions, they cannot be maintained for any considerable length of time. They act in equalizing the adjustment, very much like a spring in a machine equalizes force when suddenly applied. In quick and successive changes of the distance of small objects looked at, they temporarily preserve uninterrupted vision while the convergence and accommodation are

becoming accurately adjusted. To the surgeon a thorough knowledge of the intimate associations existing between accommodation and convergence is of the utmost importance; for upon it will in a great measure depend his success in treating many of the diseases of the eye.

In order to thoroughly comprehend the anomalies of refraction and accommodation, it is requisite for the surgeon to make his own eye myopic, hypermetropic, or astigmatic, by suitable lenses, and then study the effect produced; after which he should select such glasses as neutralize the artificial anomalies, and restore normal vision. He can then more readily understand and appreciate the symptoms described by patients, and, as a matter of course, be better qualified to diagnosticate and treat these diseases.

MYOPIA.

Myopia consists in a diminution of the distance of the far point, and when the accommodation remains normal, of a corresponding change in the near point. The eye is too long in its antero-posterior diameter, or its refractive power is so high that parallel rays are united too soon; they cross and meet the retina in circles of dispersion. For distinct vision, objects require to approach the eye in proportion to the grade of the myopia, so that rays of light emanating from them may meet the cornea as divergently as may be necessary to form the required image on the bacillar layer of the retina. The grade of the myopia is said to be low when the far point is beyond 14″; medium when it is between 6″ and 14″; and high when it does not reach 6″. In the latter case the near point is sometimes less than 2″ from the eye. To find the far point, it is usual to take moderately fine print (No. 4 Jæger), and hold it as far from the eye as it can easily be read. The distance noted represents the far point, the grade of the myopia, and the focus of a negative glass necessary to neutralize it. If the far point is found to be twelve inches, then with a concave lens of 12″ focus the patient should be able to read No. 20 Snellen at 20′.

In low and medium grades of myopia the sharpness of sight within the clear visual distance is just as great as in the emmetropic eye, and owing to the increased size of the visual angle, the myope can do fine work by a weaker illumination, and continue at it longer without fatigue. It was formerly thought that myopia was caused by too great a convexity of the cornea, but the ophthalmometer shows that it is usually less convex than in the emmetropic eye; still a conical cornea may render the eye myopic. The crystalline lens may have an excessive convexity naturally, but rarely enough so to cause any other than a low grade of short-sightedness. Long-continued work on objects requiring great accommodation may induce an excessive development of the ciliary muscle, with increased tonicity, so that it cannot readily relax and allow the lens to be adjusted for the normal far point (*plesiopia*).

Perhaps in these cases the crystalline capsule—the chief opposing power of the ciliary muscle—loses some of its elasticity, and does not contract sufficiently to give the lens the diminished degree of convexity necessary to the adjustment of the eye for the normal far point, when the tension of the muscle is reduced to its minimum.

Myopes are in the habit of partially closing their lids, in order to shut out the circumferential rays that greatly increase the circles of dispersion, and are thus enabled to get a better view of objects situated beyond the far point; hence they are sometimes called "blink-eyed." Myopia may be congenital, and is often hereditary; the most frequent cause is an excessive posterior development of the eye in the direction of its optic axis during the growth of the body in childhood (*bathymorphia*). Another cause is posterior staphyloma; this frequently attacks bathymorphitous eyes, and increases the abnormal state already developed, or it may occur in emmetropic eyes during any period of life, and is always the cause of high grades of myopia that develop after the eye has attained its normal growth. The elongation of the eye-ball in the direction of its optic axis causes it to be very prominent, to force the lids wide apart, and

to protrude more or less from the orbit; and when turned far inwards, the squarely ovoid shape caused by the pressure of the recti muscles can be plainly seen. The point of rotation of the eye is relatively moved forward on the elongated visual axis; consequently to produce different degrees of convergence, greater motion is necessary, requiring increased muscular contractions.

The ophthalmoscope may be used to find the far point; an inverted vertical image is formed very near the cornea, which the observer can see with the concave mirror by placing his eye at a proper distance. If the examiner knows the adjustment of his own eye, then find its distance from that of the patient's, subtract the distance of his own adjustment, and the result will give the far point of the eye of the patient. Children affected with myopia should exercise great care, and avoid reading or writing in dimly-lighted apartments. They should sit so as not to face the light, but to allow a clear, direct illumination to fall on the book. At school, desks should not be so low as to require the bending of the neck and body. Reading in a recumbent position should be avoided, and if at any time the eyes feel fatigued, the use of them for near vision should be at once suspended; for nothing tends more to the development of bathymorphia and posterior staphyloma than vascular excitement induced by excessive use of the eyes. By the exercise of great care, and by proper prophylactic measures, an increase of the abnormal elongation may be prevented; but a restoration of the eye to its normal condition cannot be expected: for distant vision, recourse must be had to a lens with a negative focus of sufficient power to render parallel rays as divergent as may be necessary to make the proper retinal image. The farthest distance at which the patient can read moderately-sized print, gives us his far point, and its distance from the eye, measured from the nodal point, gives the focus, theoretically, of the lens required to neutralize the myopia. If the far point be 12″, then a lens of — 12 inches focus would be the proper one to make his $V = 1$;

that is, to see at an infinite distance—No. 20 Snellen, at 20.'* Practically, a concave glass of 12 inches focus is found to be a little too strong; for the convergence of the visual axes at 12″ prevents the eyes from accommodating themselves for the normal far point; hence we should by means of trial lenses select those that are exactly adapted to his case, and render vision most easy and distinct.

In short-sightedness of medium and high degrees there is frequently a deficiency of relative accommodation, so that should the error of refraction at once be entirely neutralized, it would give rise to muscular asthenopia; hence it is better to begin with weaker glasses, and increase them from time to time for those of higher power, until the proper ones can be worn. This course allows the natural relations existing between accommodation and convergence gradually to become accustomed to the changed conditions of association.

Myopia of very high grade cannot be entirely neutralized; owing to the distance of the glass from the eye, the image is so reduced in size that the object has to approach very near the cornea, in order to attain the necessary visual angle. In medium and high grades of the disease, the same glass will not answer for near and distant vision; for it is necessary that the ray of direction should pass through or near the centre of the lens. If the spectacles are adjusted to see at a distance—then for near vision, owing to the great convergence of the visual axes,—the light lines would pass through the glasses at a considerable distance from their centres, which would bend them the same as prisms with curved surfaces; consequently, for near vision the centre of the glasses should be made to approach each

* In the calculations for the adjustment of spectacles, I have neglected to take into consideration the distance of the glass from the eye. This is unnecessary, unless the required glasses are of very high power. If, for instance in myopia, the far point be 6″, and the glass is half an inch from the eye, then its focus should be $5\frac{1}{2}$ inches; on the contrary, in high grades of hypermetropia the focal length of the required glass should be increased by its distance from the eyes.

other, so as to correspond to the visual lens from the point of fixation.

For binocular near vision in high grades of myopia—owing to the visual axis frequently cutting the cornea outside of its zeninth, and to the antero-posterior elongation of the eye-ball,—it requires excessive exertion of the internal recti muscles to converge the visual axes to the point of fixation. If the disease has been slowly developed, often these muscles attain abnormal strength and development, so as to be capable of sustaining, for a long time, a great degree of tension, but usually after a while the muscles tire; one of them fails, and the eye turns outward. After a short period of rest this muscle regains its power, but if used too soon speedily becomes fatigued again, and we have muscular asthenopia. This becomes so troublesome that patients often give up binocular vision, and turn the eye not used outward, so that rays of light from the object may strike a part of the retina least sensitive, and cause less disturbance to the retinal image of the other eye. The patient learns to suppress the image of the unused eye, which, from want of use, soon in a great measure loses its sharpness of vision (*anæsthesia optica* or *amblyopia ex anapasia*). Most of the cases of divergent strabismus arise from this cause.

HYPERMETROPIA.

Here the far point is removed from positive infinity to a negative distance. The reverse occurs from what we find in myopia; the refractive power of the dioptric media is too low, or the eye is too short in the diameter of its optic axis, so that parallel rays meet the retina before they are united in a focus, and objects are seen in circles of dispersion. Hypermetropia is divided into facultative, relative, and absolute. In the former the far point is behind, and the near point in front of the retina. A part of the accommodation is necessary for distinct vision of distant objects. The near point may recede until it becomes the normal far point; then the entire power of accommodation is exhausted; slightly beyond this, vision may be rendered pos-

itive by giving up binocular vision and converging the optic axes to a point nearer than the one of binocular fixation (*relative hypermetropia*); for when the accommodation remains normal the near point may be brought nearer, and the far point receded by the convergence or divergence of the optic axes. When the eye fails to unite parallel rays on the retina by the aid both of the accommodation and excessive convergence, it is absolutely hypermetropic—the clear visual distance is entirely negative.

Children and young persons with hypermetropia, when they are required to read, write, or perform other occupations demanding near and sharp vision, soon learn by experience the increase of power of accommodation gained by excessive convergence of the visual axes. A part of their accommodation being used for distant vision, for the near point, it requires the maximum tension of the ciliary muscle, which soon tires, and the object becomes indistinct; then the child finds that by squinting inward he can restore the sharpness of sight with less strain of the accommodation. At first the squint is periodic, the eyes becoming parallel as soon as they are removed from the object, but speedily returns if near vision is resumed, and the squint eventually becomes permanent. It is said that seventy-five per cent. of the cases of convergent strabismus arise from this cause. The hypermetrope frequently learns to read very fine print by holding it an inch or two from the eye; he attains wonderful facility in this respect, and is often thought to be very near-sighted. The visual angle increases in an inverse proportion to the distance of the object; hence, it becomes very large when the print is held near the eye. By contracting the pupil and partially closing the lids, so as to shut out as much as possible the circumferential rays, the circles of dispersion are largely diminished; then by a forced uniform contraction of the recti muscles the print becomes clear and distinct.

I believe that the strong contraction of these muscles, attached, as they are, anteriorly near the margin of the cornea and posteriorly around the optic foramen, with their broad bel-

lies resting on the equator of the partially yielding eye-ball, lessens its transverse diameter and slightly increases its length in the direction of its optic axis. The lessening of its transverse diameter exerts a direct pressure on the equator of the lens, and renders it more convex than it can be made by the maximum tension of the ciliary muscle. This accounts for the increased accommodation caused by convergent squint; here the excessive action of the internal rectus requires an increased tension of the other recti muscles, in order to steady the eye. A greater lateral pressure is the result, which extends to the equator of the lens. One can easily prove this by trying the experiment on his own eye. Take No. 1 Jæger, and hold it one and a half inches from the cornea; let the book and the eye be well illuminated, contract the pupil, partially close the lids, and exert the full power of the ciliary muscle; the print is seen in circles of dispersion; now forcibly contract the recti muscles, and instantly it will become very black, sharply defined, and twice or thrice its natural size.

Hypermetropia may be hereditary, and is often congenital, but the most frequent causes are senile involutions in the eye with advancing age, and in children the arrest of the growth of the sclerotica in the direction of its optic axis, making the eye too flat (*pathymorphia*), which is also small and deeply set in a shallow orbit, giving the face a peculiar flattened appearance. In young persons the disease is often masked; a portion of the power of accommodation being exhausted in adjusting the eye for parallel rays, the ciliary muscle, by unusual strength and activity, *may* bring the near point to its normal distance, so that V still equals 1.

The hypermetropia may be detected by placing before the eye of the patient the strongest convex glass with which he can read No. 20 Snellen at 20′; but this does not give the real grade, because he cannot completely relax the muscle of accommodation. Hence it must be paralyzed by the repeated instillations of atropia; then the number of the lens required to read No. 20 Snellen gives the grade of the disease. In well marked

plathymorphitous eyes, and in hypermetropia of high grade, the sharpness of vision is always diminished, and cannot be entirely restored by the use of convex glasses. Here, as in myopia, children should exercise great care, and avoid straining their eyes by reading, writing, or doing fine work by an insufficient illumination. Convex glasses should be selected that just neutralizes the latent hypermetropia; these are to be used for near vision only, and should enable the facultative hypermetrope to accommodate for the near point with the same ease, and continue to do so as long as those with emmetropic eyes, and prevents the development of convergent squint. In absolute hypermetropia, theoretically, different convex glasses are required for every change in the distance of the object, but in practice two pairs of spectacles will ordinarily suffice; one pair should be selected that enables the patient to distinctly see No. 20 Snellen at 20′. Then another pair of sufficiently high power to make No. 1 easily read at from 8 to 10 inches.

PRESBYOPIA.

Presbyopia is simply a recession of the near point with advancing age, and consequently, sooner or later, affects all persons. The near point gradually recedes from childhood, but it is not usually noticed until about the age of forty or forty-five years, when, in reading or looking at small objects by artificial light, or by day in dimly-illuminated apartments, vision becomes indistinct, and the object has to be removed to a considerable distance from the eyes; this reduces the size of the visual angle to such an extent that the eyes soon tire, become painful, and the reading has to be suspended. By increasing the light, easy vision is at once restored. This is because a stronger light contracts the pupil and shuts out the circumferential rays that meet the retina in circles of dispersion. Soon the near point becomes so distant that in the most favorable illumination small objects, as print, for instance, cannot be sharply seen—the letters are blurred and indistinct. According to Donders, presbyopia commences when the near point has

receded beyond 8″, and this rule has been generally adopted. I am satisfied that in this country, particularly in the South and West, the normal visual angle is less than five minutes.

From a large number of tests, I have found that most persons have clear and sharp sight with a visual angle of four minutes. In Germany, and some other European countries, the inhabitants are proverbially short-sighted. An angle of five minutes is the smallest one (except in small children) at which they can ordinarily see with distinctness. For generations a large proportion of the population have been accustomed to work in doors, frequently in manufactories, requiring constant strain of accommodation. Those who receive a liberal education are unusually studious, often spending for years twelve or fifteen hours daily in reading, writing, etc. These habits long continued have had a marked influence on the formation of their eyes, gradually diminishing the distance of the far point. Here we have exactly the reverse; the people have, as a rule, been reared in the rural districts; as children, they have roamed over our hills and prairies, and by their amusements and occupations, have cultivated sharpness of sight for distant objects. They rarely spend much time in close study, or learn trades requiring constant exercise of the accommodation, such as engraving, watch-making, etc.; nor have we manufactories that demand an unusual amount of sharp vision for minute objects. The result is that, as a people, we are far-sighted. It is rare to find one here, under thirty-five years of age, who cannot easily read No. 1 Snellen at 20″, and No. 20 at 30′, ($V = \frac{20}{12}, \frac{30}{20}$), far more exceeding this than falling short of it. Under thirty, I find the near point from 5″ to 6″, evidently more distant than it is, as a rule, in Germany. These views being established, I think that with us 8″ is too near for the starting point of presbyopia.

I have for some years in my practice made it 10″, with the most marked favorable results in preventing the rapid increase of senile changes, and preserving the sight with but comparatively slight impairment to advanced age. If the recession of

the near point beyond 8″ is taken for the commencement of presbyopia, then when it has become 12″, to bring it back to 8″, it requires a lens of 24″ focus, for $\frac{1}{8} - \frac{1}{12} = \frac{1}{24}$; whereas, to bring it to 10″, it would require a glass of 60″ focus, for $\frac{1}{10} - \frac{1}{12} = \frac{1}{60}$. Owing to the power of accommodation gained by the convergence of the optic axes, these numbers would be a little too strong, and $\frac{1}{30}$ and $\frac{1}{72}$ would, in practice, be found to answer the required purpose.

In all theoretical calculations, the eye is considered simply as a dioptric apparatus; to render these results practical, the associations existing between the ciliary and internal recti muscles must be taken into consideration. Glasses that would, theoretically, neutralize the errors of refraction, are usually too strong; "they compel the muscle of accommodation to a relaxation greater than corresponds to the developed circumstances of association." Surgeons often forget this important consideration (and opticians who adapt most of the spectacles are generally ignorant of it, as they are of the theory of refraction and accommodation), and recommend glasses that are too strong, and consequently absolutely injurious. Every ophthalmic surgeon should have a complete set of trial lenses, with numbers ranging at least from 2 to 72 (and I would prefer to 96), and by actual tests find the number that will enable the patient easily, and for a long time, to read moderately fine print held from 12″ to 14″ from the eyes.

The habitual use of glasses too strong in the commencement of presbyopia is a most powerful factor in inducing rapid senile changes in the lens and muscles of accommodation. The ciliary muscles are relaxed, and only required to contract to a certain point; they soon become enfeebled, and lose the power to act beyond their accustomed tension; this state of tension soon indicates their maximum strength, which cannot long be maintained; hence, lenses of higher power must be substituted to relieve the strained accommodation.

Now, this substitution of convex lenses for accommodation from muscular power has a direct influence in increasing the

firmness and solidity of the crystalline lens. The latter is of a jelly-like consistency, that is, constantly changing its shape as it is acted upon by opposing forces. In children it is quite soft and supple, but its firmness increases with advancing age, so as to require additional force to produce the same amount of change in its curvatures; the necessity for these changes are lessened just in proportion to the strength of glasses used; consequently, as the motion of its particles on each other are proportionally diminished, these lose their suppleness, become firm, and offer increased resistance to the already enfeebled accommodation. The result is, that strong glasses weaken the muscle of accommodation by diminishing the necessity for its action; this produces an increased firmness of the lens by lessening the motion of its particles on each other, and this in its turn reäcts on the muscle, by demanding increased action from its already weakened fibers.

Both of these factors, acting and reäcting on each other, causes a rapid increase of the presbyopia and the early commencement of hypermetropia. Now the question arises, What is ordinarily the proper focus of convex glasses suited to one who first notices difficulty in seeing distinctly in dimly-lighted apartments? I have already stated that I have found No. 72 answer all the required indications and give perfect satisfaction.

In reading a work by Sichel, published at Paris in 1848, entitled "Spectacles, their Uses and Abuses," I became strongly impressed with the practical views he advocated in regard to the use of the low numbers of glasses in commencing presbyopia. He says, "Generally speaking, opticians commence with too powerful numbers, and augment too rapidly their refractive force. Ten years ago they nearly always took No. 48 as their starting point, and patients were soon forced to descend to Nos. 36 and 24. The result was, that it was common to see persons between the age of fifty and sixty years making use of glasses between Nos. 12 and 8, and complaining, as we shall soon explain, that even then they saw but dimly, and that their

sight declined from day to day. . . . From the results of my observations I have taken No. 72 as a point of departure; which number, in general, is suitable for those who have not yet begun to use spectacles, and who assume them at the opportune moment, that is, at the age of forty or a little later. Often, however, especially for those below forty, Nos. 80 and 96 are entirely sufficient during a long time. At first the opticians of Paris deemed the use of too feeble glasses singular, and even ridiculous, regarding them as almost without force. . . . Little by little, they have seen this practice sanctioned by its results. . . . The method of beginning by the highest numbers has now been generally adopted, and I see persons every day to whom the opticians have recommended the use of convex glasses No. 72, and who have been perfectly satisfied with those during several years. It is an error to assert that it is absolutely necessary to change them (the spectacles) from time to time. On the contrary, it is best to change them as rarely as possible; and not at all, if a necessity for doing so is not felt. It is only through commencing by too powerful numbers, and neglecting hygienic rules, that the necessity is created for changing soon and often."

For some years I have acted on the views so forcibly expressed by M. Sichel, with results so favorable, that I wish every ophthalmic surgeon and optician would give them a trial. While penning these lines a gentleman fifty years of age called at my office, who has for several years been using glasses No. 72, and can read with them, by good light, for hours without experiencing the slightest fatigue. For night-reading, or by artificial illumination, he now wears No. 60, but he never puts them on in the day-time, unless in a badly-lighted room. I tested his eyes, and found that he read with his left eye No. 1 Jæger at 12″, with his right at 15″; by the aid of glasses No. 72, he read with left eye at 8′, with right at 12.″

His eyes up to the commencement of presbyopia had always been emmetropic. I know many persons past the age of forty-five years who, acting upon my advice, wear glasses No.

72, and have not felt any necessity for an increase of their power. I was recently consulted by a gentleman about sixty years of age, who requested me to select for him appropriate glasses; his sight had failed so that he had difficulty in reading. I found that he began the use of glasses that magnified considerably, and had frequently changed them for those of still higher power, until he was at that time using No. 7 for near vision, and No. 16 for seeing at a distance. On testing his eyes with trial glasses, I found that he saw better at a distance with No. 18 than with No. 16, thus showing that he had even gone beyond actual necessity in increasing the strength of his glasses, and his eyes were suffering in consequence.

In making trials for the selection of proper spectacles, the patient should always begin with those that are a little too weak, and increase the numbers until he finds a pair that makes the letters at 12″, or 14″, look clear, distinct, sharply defined, and of the natural size—as near as possible as they looked before his eyes were presbyopic. If he makes trial at first of those that magnify too much, it interferes with his judgment; the objects look unnaturally large, bright, and distinct; when the really proper glasses are found, he compares the impression they produce with those of the stronger ones, and is dissatisfied with them.

Empirics often take advantage of this, and select strong glasses for their patrons, who, finding that objects appear unnaturally clear and bright, imagine that it is owing to some peculiar quality in the material, or to the manner in which the lenses are made, and are ready to testify to the wonderful skill of the maker or vender. After a few weeks' use, however, they find the eyes become painful, sensitive to light, inflamed, and the glasses have to be laid aside. In the meantime, the vender has sought other fields to dispose of, at fabulous prices, his "marvelous spectacles."

Many are prejudiced against glasses, and decline to wear them when their use is imperatively demanded. This is wrong; in attempting to look at small objects, they strain the accom-

modation by requiring it to act beyond its strength. The result is accommodative asthenopia, which, if not promptly relieved by giving up near vision, or by wearing appropriate glasses, terminates in hyperæmia of the retina, ciliary neuralgia, redness of the conjunctiva, and which, if allowed to continue long, may end in incurable amblyopia. To preserve the sight unimpaired the longest possible time, it is requisite, as soon as it begins to fail, to select the weakest glasses that will make vision easy; and as the failure at first is barely perceptible, very slight assistance is needed, and spectacles, Nos. 84 or 72, are all that is required.* On first adjusting the eye for reading, should the print seem a little indistinct if it is carried off at arm's length and then brought near the eye, and this repeated three or four times, then at the normal distance the print can be easily read without fatigue. This action accounts for the temporary increase in the power of the eye to adjust itself for the near point, sometimes seen after the use of the so-called "eye cups" and "sight restorers," so extensively advertised by empirics, the action of which is to lessen the transverse diameter of the eye-ball, and thus by pressure on the equator of the lens, forcibly to loosen the particles of the latter, which have been rendered too firm by senile changes. The lens is thus temporarily made softer and more supple, so that it opposes less resistance to the action of the ciliary muscle.

ASTIGMATISM.

The cornea is not a section of an ellipse rotated, but of one with three diameters, the shortest of which is vertical, the next horizontal. This makes the vertical meridian more convex than the horizontal. The maximum and minimum curvatures

* It is difficult to procure low numbers of spectacles outside of metropolitan cities. Few opticians can be prevailed on to keep them. They may be obtained up to 72-inch focus from Jas. W. Queen & Co., No. 924 Chestnut street, Philadelphia, and will be forwarded by mail on application to them. Of course, if opticians will generally keep low numbers, there will be no necessity for ordering them from a distance.

are usually perpendicular to each other, and both are perpendicular to the long axis of the cornea. The crystalline lens also varies in its different meridians, but the maximum curvature is usually horizontal, and the minimum vertical, so that the lens partially neutralizes the astigmatism of the cornea.

For the better understanding of the irregular refractions causing astigmatism, it is well to describe the effect on two planes of homocentric light from a bundle of rays passing through a small round hole in a window-shutter in the direction of the prolonged optic axis; one plane passing through the meridian of the maximum, the other through that of the minimum curvature. If a thin metal plate with two narrow slits cut in it, crossing and standing perpendicular to each other, is placed before the eyes, so that one slit shall correspond to each of the principal meridians of the cornea, it will permit two planes of the homocentric bundle of rays to pass into the eye. The vertical plane, passing through the maximum curvature of the cornea, will first meet at a point. If we imagine a shade held at this place, the horizontal rays not yet having united will form a horizontal line on the shade. A little further back the still converging rays will be crossed by rays of the vertical plane, which has already met and are now diverging; at a certain place these lines will be of equal length. Still further back the horizontal rays meet in a point, and the vertical ones form a vertical line on the shade a little longer than the anterior horizontal one. The former is called the anterior focal line, the latter the posterior. A line drawn through the points of meeting of the two planes of light represents the focal tract. The point of crossing of the two lines of equal length is a little anterior to the middle of this line, and is called the middle focus. We will now remove the plate from before the eye, and allow the entire bundle of rays to fall on the cornea, and trace the changes produced on them.

If we imagine the shade to be held in front of the anterior focal line, the bright spot will be of an oval shape with its long diameter horizontal; as the shade moves backward, its eccen-

tricity will increase until at the point of union of the rays of the vertical plane, it will be drawn out into a horizontal line; passing backward, it again becomes oval, but the eccentricity decreases, until at the middle focus, it will be nearly circular; after which it again becomes oval with long diameter vertical; its eccentricity increases until at the point of meeting of the rays of the horizontal plane, the crossed rays form a vertical line. Passing the shade still backward, the bright spot again becomes oval with long axis vertical.

At the middle focus, where the image appears circular, two planes of light meet, each passing through meridians of the cornea at angles equally distant from the vertical and horizontal meridians; here is the greatest concentration of rays with the smallest disturbance from circles of dispersion; consequently, if the eye can be so adjusted as to bring this focus on the retina, it gives the most distinct vision.

Nearly all eyes are astigmatic, but not enough so to disturb the sharpness of vision. This is called *normal* regular astigmatism. By looking through a stenopäic slit, vertical lines are seen at a greater, and horizontal lines at a shorter distance.

When the difference in the refractions of the several meridians is so great that vision is disturbed, it is called *abnormal regular astigmatism.* To detect this, various means have been employed. Graefe invented an optometer, composed of fine wires crossing each other at right angles. At a certain distance, corresponding to the focal point of one of the principal meridians, one set of wires are seen, while the others crossing them are indistinct or not seen at all. Another method is by making numbers of groups of three lines, parallel to each other, diverge from a point like the spokes of a wheel. If this figure is moved away from the astigmatic eye when it arrives at a certain point, only those groups will be distinctly seen that correspond to the meridian of a certain curvature of the cornea. If the figure be moved further off, or the accommodation be changed, other groups of lines will become very black and sharply defined, while those first seen are pale and indistinct.

By looking through a slit in a stenopäic instrument, or through a narrow slit cut in a thin blackened metal plate at a round or square object of sufficient size to give parallel rays at 20′ distant, and placing behind the slit a convex or concave glass that renders the object most distinct, the focal length of the glass required gives the grade of the myopia or hypermetropia of that meridian. If the head is erect, each of the two principal meridians can easily be found; they usually stand perpendicular to each other, and correspond with the vertical and horizontal meridians of the cornea.

Another very satisfactory test for astigmatism, is by means of a hole half a line in diameter, made in the window-shutter of a darkened room, or a small round hole in a blackened metal cylinder placed over a lamp. If there be abnormal astigmatism, the light passing through the round hole appears oval, or it will be drawn into a vertical or horizontal stripe, varying according to the adjustment of the eye or its distance from the hole in the shade or shutter.

If the daylight is passed through dark violet glass, or the lamplight through dark cobalt, to the astigmatic myope, the image will appear red with a blue border; to the astigmatic hypermetrope, blue with red border.

Abnormal regular astigmatism is divided by Donders into simple, compound, and mixed. In the simple form the eye is emmetropic in one of its principal meridians, and myopic or hypermetropic in the other, and is expressed $E - \frac{1}{\infty} = 0$; the astigmatic deviation $Ah = \frac{1}{a}$ or $Am = \frac{1}{a}$. If we find an eye normal in the horizontal meridian, and myopic $= \frac{1}{20}$ in its vertical, then $Am = \frac{1}{20}$; the proper lens to correct it would be a cylindrical concave of 20″ focus, axis horizontal.

If the vertical meridian be normal, and the horizontal hypermetropic $= \frac{1}{12}$, then $Ah = \frac{1}{12}$, and a convex cylindrical glass of 12″ focus, axis vertical, would neutralize it.

Compound astigmatism: here the eye is myopic or hypermetropic in all of its meridians, but not of a uniform grade; it is simple myopia, or hypermetropia with astigmatic variations.

If there be in the vertical meridian $M = \frac{1}{48}$, and in the horizontal $M = \frac{1}{16}$, then it is expressed $M = \frac{1}{48} + Am\ \frac{1}{24}$, for $\frac{1}{48} + \frac{1}{24} = \frac{1}{16}$, which is a myopia of $\frac{1}{48}$ with an astigmatic variation of $\frac{1}{24}$. To correct this, it requires a spherico-cylindrical lens, one of the surfaces of which should be ground spherical concave $\frac{1}{48}$, the other cylindrical concave $\frac{1}{24}$; written $-\frac{1}{48}$ s $\bigcirc$ $-\frac{1}{24}$ c, axis vertical.

If there be in the horizontal meridian $H = \frac{1}{30}$, and in vertical $H = \frac{1}{12}$, it is expressed $H\ \frac{1}{30} + Ah\ \frac{1}{20}$, and requires a lens one side spherical convex $\frac{1}{30}$, the other cylindrical convex $\frac{1}{20}$; expressed $\frac{1}{30}$ s $\bigcirc$ $\frac{1}{20}$ c, axis horizontal.

Mixed astigmatism is where myopia exists in one of the chief meridians and hypermetropia in the other; here, as the hypermetropia in reference to the far point has a negative value as compared to the myopia, the astigmatic deviation is found by adding the refractive state.

If there be $M = \frac{1}{10}$ in vertical, and $H = \frac{1}{15}$ in horizontal meridian, then $Amh = \frac{1}{10} + \frac{1}{15} = \frac{1}{6}$. This may be corrected by a bi-cylindrical lens, one of whose surfaces is cylindrical convex $\frac{1}{15}$, the other cylindrical concave $\frac{1}{10}$; written $\frac{1}{15}$ c $\ulcorner$ $-\frac{1}{10}$ c, axis of concave surface to correspond to horizontal meridian.

The above may also be corrected by a spherico-cylindrical lens, but the bi-cylindrical is preferable, on account of the prismatic deviation and lateral distortion of objects that would be caused by the strongly-curved surfaces of the former.

Irregular astigmatism is where planes of light in single meridians are broken up, so as to unite at two or more points. It arises from irregularities, either of the cornea or lens, and gives rise to diplopia, monocular polyopia, stellated figures of dispersion, etc., that cannot be entirely removed by correcting glasses.

The asymmetrical formations of single meridians of the cornea, giving rise to doubling or multiplication of images, is usually the result of a shrinkage of cicatrices following wounds or ulcers; and generally, owing to the higher refractive power of the cornea, is much more disturbing to vision than when the irregular refractions in single meridians arise from inequalities in the sur-

faces of the lens. As these cicatrices usually only affect certain parts of the cornea, it is sometimes requisite to cut out a portion of the iris, and thus make a new pupil, so as to admit the light through some portion of the cornea still retaining its normal curvatures.

Astigmatic glasses should be made round, set in spectacle frames, and so adjusted that the axes of the cylindrical surfaces shall be exactly perpendicular to the direction of those principal meridians having the greatest abnormal deviations.

In high grades of astigmatism the same spectacles will not answer for distant and near vision. In converging the visual axes, the planes of the different meridians vary according to the amount of convergence, and perfect vision requires for each variation a new adjustment of the axes of the cylindrical surfaces. Slight differences do not seriously lessen the sharpness of sight, but in attempting to look at minute objects through spectacles adjusted for the far point, the variation of the axes of the cylindrical glasses from the meridians to which they should correspond, is so great as to give rise to prismatic deviations and lateral distortion of objects, so disturbing to vision as to be unbearable to the patient. Hence, for near vision the glasses should be made to approach each other according to the amount of required convergence, and their surfaces should be so set as to be parallel to the planes of the pupils.

ASTHENOPIA.

The normal eye is adjusted for parallel rays, and only requires to be properly directed towards distant objects to give clear vision. To see distinctly near objects, the rays from which meet the cornea divergently, requires an adjustment produced and maintained by muscular action. Asthenopia is a want of sufficient potential muscular energy to maintain for any considerable length of time the proper adjustment of the dioptric apparatus for near vision of small objects, and the nervous and vascular excitement caused by the effort. If there is an insufficiency of the ciliary muscle, it is called *accommodative* asthenopia; if of

the internal recti, it is distinguished as *muscular* asthenopia. The former is more frequently met with, and shows itself, for instance, in reading fine print; it is at first seen clearly, and sharply defined, but after a time it gradually becomes blurred, the borders widen out and grow indistinct; if the effort is continued, it is followed by pain in the eyes and forehead, lachrymation and conjunctival redness. If the book is laid aside, these symptoms quickly disappear, but return if the reading is too soon resumed. The frequent straining of the accommodation in looking at near objects sometimes weakens the ciliary muscle to such an extent that it can maintain its adjustment but for a moment. The forced effort of the retina to catch a clear impression of an indistinct image causes it to become irritable, sensitive to light, and hyperæmic, accompanied by ciliary neuralgia, and redness of conjunctiva, rendering the eye unfit for use; hence near vision has to be for a time given up.

Accommodative asthenopia is often the result of severe exhausting illness, which disappears with increasing strength. Children of delicate organization and lax muscular fibre often suffer with it when they attend school. By far the most frequent cause is facultative hypermetropia; here a part of the accommodation is used for parallel rays; hence for near vision it requires a forced action of the ciliary muscle, whose potential energy becomes exhausted if the effort is too long continued. Muscular asthenopia is also attended with retino-ciliary irritation; but here objects run into and overlap each other, or are seen double. It is most generally found in bathymorphia, and in high grades of myopia, where, for binocular vision, great convergence of the optic axes are necessary. If the myopia has progressed slowly, the internal recti muscles may have gradually increased in size and strength sufficiently to perform the excessive labor demanded of them; but often, particularly if the disease has developed rapidly, there is a want of power of one or both of these muscles to long maintain the required tension; one fails and permits the external rectus to turn the eye outward, and the object is then seen double. When once the insufficiency of an

internal rectus has manifested itself, it does not readily regain its strength, even after a considerable period of rest; and it becomes less and less able to sustain prolonged action, until finally the insufficiency is so annoying that artificial assistance must be rendered, or binocular vision has to be given up. The weakness of the muscle can easily be shown by directing the patient to read fine print, held in the horizontal plane, or a little lower, before the eyes, and watching the result; soon one eye will be seen to waver for a moment, and then deviate outwards. Another test is to place a weak prism before one of the eyes when adjusted for near vision, with its angle up or down. Few eyes can overcome a prism of 2° with its refractive angle upwards or downwards, so as to fuse the double image, one of which will appear in a vertical line above the other. Single vision once removed, a muscle overstrained gives way, and seeks an equilibrium with its opponent according to the relative strength of the two. When normal eyes are adjusted for the far point, only very weak prisms, with their angle outwards, can be overcome; but with the angle turned inwards, the internal rectus can overcome a prism of from 20° to 30°, so as to fuse the double image; but this difference diminishes as the object approaches the near point, where the power of abduction and adduction is nearly equal. Here, if there is an insufficiency of one internal rectus muscle, the extent of it can be found by placing before one of the eyes a weak prism with its angle up or down, while looking at a small ink spot on a piece of paper; soon the weakened muscle will waver, then give way, and the eye will turn outward. There will be two images of the object some distance apart laterally, and in different planes. Another prism with its angle outward, that will make these images stand in a vertical line one above the other, represents the degree of the insufficiency.

In the treatment of asthenopia, care must be taken to avoid all work that strains or fatigues the eyes. The illumination should fall properly on the object, and not too direct on the eyes. Reading, writing, sewing, drawing, etc., should

only be attempted in a good light, and then given up on the first appearance of symptoms of fatigue. In the accommodative form, recourse must be had to convex glasses to relieve the overburdened muscle, and these must be of a power to correspond to the insufficiency; if this is slight, weak glasses will suffice, and nothing else is required; but if it is of a higher degree, stronger ones must be worn; but these destroy the associations that exist between accommodation and convergence beyond what relative convergence can overcome; hence, the convex glasses must be combined with a weak prism, with its angle outward. The lens should be ground on the surfaces of the prism, so as to combine both in one glass.

Muscular asthenopia being usually the result of myopia, requires concave glasses in order to remove the apparent distance of the object, and thus diminish the convergence of the optic axes. These may answer where the myopia is of low degree, but in the higher grades negative glasses that would neutralize the insufficiency of the internal recti muscles by diminishing the convergence, would so reduce the size of the image as to render vision indistinct; hence, the overburdened muscles must be relieved by weak prisms with angles outwards. Generally, prisms whose refractive angle is a little less than the amount of insufficiency answers, combined with negative glasses that enables the patient to do moderately fine work without fatigue to the eyes. Where the insufficiency of only one muscle is considerable, it is better to divide the prismatic correction between the two eyes, as strong prisms cause chromatic aberrations and lateral distortion of objects very troublesome to the patient. Some surgeons have advised the laying back the attachment of the external rectus muscle, and thus weaken the opposing power to the rectus internus, but the results have not been very satisfactory.

REMARKS.

For most of our knowledge of the diseases of refraction and accommodation, we are indebted to the researches of that won-

derful people the Germans, who at the present day surpass all other nations in diving into the hidden depths of Nature, in order to investigate the mysterious secrets of her workings, and then applying the knowledge thus attained to benefit mankind and to relieve human suffering.

Among those worthy of all honor in connection with the subjects of this article, I would mention Hemholtz, Donders, Graefe, Knapp,* Arlt, Stellwag, Jaeger, and Hering, who, with their fellow-colaborers, have, in less than a quarter of a century, built up an entirely new science in this department of ophthalmology.

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* This world-renowned Ophthalmologist has recently made America his home.